4

INVESTIGATION OF OCCUPANT INJURY POTENTIAL IN VEHICLE REAR IMPACTS

Donald J. Crane

Recognition of Contributors

David M. Bapst
Calspan Corporation

Robert Fatchett
Explorer Van Company
Warsaw, Indiana

Robert Pilarczyk
Mark III Industries
Ocala, Florida

November 1, 1992

Calspan Corporation
Advanced Technology Center
Transportation Sciences Center
4455 Genesee Street
Buffalo, New York 14225

Paper was presented at the 20th Annual Workshop on Human Subjects for Biomechanical Research. This paper has not been screened for accuracy nor refereed by any body of scientific peers and should not be referenced in the open literature.

Abstract

This paper summarizes the results of rear impact tests conducted on two different full size conversion vans. The tests were conducted following a procedure similar to that used in testing according to the Federal Motor Vehicle Safety Standard (FMVSS) 301, "Fuel Integrity Tests". However, additional dummies, instrumentation, and cameras were used to assist in evaluating the potential occupant injury. It will be shown that the resulting injury levels were quite low for the dummies and that the seatback failure was virtually nonexistent. The additional instrumentation also provided a means of comparing the dynamic seatback loads to those collected statically by performing an FMVSS 207 "Seating Systems" test.

Introduction

Recently, the general public has been made aware of potential safety problems related to seatback failure during rear impacts. This has been disseminated through News programs and various special vehicle safety groups. The contention is that during a rear impact, the seatback could fail, causing the occupant to be thrown into the rear seat or possibly ejected out the back of the vehicle. Data from the 1990 General Estimates System (G.E.S.) reveals that about 22% of the passenger cars involved in rear crashes involve minor or moderate injury, while just over 10% involve severe or fatal injury. For light trucks, vans, and utility vehicles about 21% of the vehicles involve minor or moderate injury and about 8% involve severe or fatal injury. The van conversion industry is particularly interested in seat strength because one of its main marketing points is to replace Original Equipment Manufacturer (O.E.M.) seats with more comfortable and luxurious seats that will also assist in protecting the occupant in both front and rear collisions. Many van converters, including Explorer Van and Mark III, have tailored their designs with the FMVSS 208 "Occupant Protection", FMVSS 207 "Seating Systems" test requirements in mind. Also, due care testing has been performed to monitor seat and occupant performance in rear crashes.

Vehicle Description and Preparation

The vehicles used in the testing were full size Chevrolet G-Vans. One vehicle was converted by Explorer Van and the other was converted by Mark III. The conversion included installing captains chairs and sofa chairs, installing side windows, raising the roof, and installing additional trim items. The captains chairs were placed on the left and right sides of the vehicles at both the forward and middle seating positions. The sofa chairs were placed at the third seating position. A total of seven dummies were used in each test. The following table displays the test dummies used for each of the vans.

Seating Location	Explorer Van	Mark III Van
Driver (left) Seat	50th %ile, P572, ballast	50th %ile, P572, ballast
Passenger (right) Seat	95th %ile, ballast	50th %ile, P572, ballast
Left Middle Seating position	50th %ile, HIII, instrumented	50th %ile, HIII, ballast
Right Middle Seating position	95th %ile, instrumented	50th %ile, P572, ballast
Left Sofa Seating position	50th %ile, P572, ballast	50th %ile, P572, ballast
Center Sofa Seating position	50th %ile, HIII, instrumented	50th %ile, HIII, instrumented
Right Sofa Seating position	50th %ile, P572, ballast	50th %ile, HIII, ballast

Table 1 - Test Dummy Locations and Type

The instrumentation used in the 95th was head x, y, z and chest x, y, z accelerometers. The instrumented Hybrid III (HIII) dummies contained head x, y, z; chest x, y, z; pelvis x, y, z accelerometers, and neck x, y, z force and moment transducers. All the test dummies were centered on their seats in a "normal" driving/riding position. The dummies were belted to prevent any forward motion during rebound and the head restraints were set to support the center of the head.

In order to measure the dynamic seatback load, a load cell was tethered to the upper seatback of a front seat. For the Explorer van the right front (passenger side) seat was used and for the Mark III van the left front (driver side) seat was used. For the Explorer van, a 95th percentile dummy was placed in the right front seat, and another 95th was placed in an identical captains chair behind the front seat. In the case of the Mark III van, a 50th percentile dummy was placed in the left front seat, and another 50th was placed in an identical captains chair behind the front seat. The captains chair used in each of the vehicles were not the same. Therefore, for each vehicle, an experiment and control system was set-up. The load cell measuring system was designed by building a rigid structure at the front of the vehicle that was capable of mounting a load cell. A piece of high strength seat belt webbing was then attached to the load cell and to the upper structure of the seatback. When the seatback was loaded by the dummy, the load cell was put in tension.

Other vehicle instrumentation included left and right B-pillar accelerometers, and left and right C-pillar accelerometers, used to measure the crash pulse of each vehicle in the longitudinal (x) direction. Eight (8) high speed cameras were used to photograph the event. Two (2) cameras viewed the crash from the left side and two (2) from the right side. Four (4) cameras were placed on-board to document the occupant kinematics. One (1) camera recorded the front seat that had the load cell tether, while the other three (3) focused on the individual seating position rows. The final test weight of the Explorer van was 7500 pounds and the weight of the Mark III van was 6180 pounds.

Test Procedure

The test procedure used was very similar to that used in the FMVSS 301, "Fuel System Integrity" test procedure. One portion of that test procedure requires a flat faced rear moving barrier to strike the rear of a stationary test vehicle at 30 mph. The moving barrier had a weight of 4000 pounds, and did not have any instrumentation. FMVSS 301 requires only Part 572B ballast dummies at each of the front outboard designated seating positions (DSP) of the target or test vehicle and may be equipped with accelerometers to measure the crash response. Typically, the event is recorded with one stationary high speed camera. Therefore, it can be seen that in two tests performed using the converted vans, much more instrumentation and camera coverage was used to document and investigate the crash event.

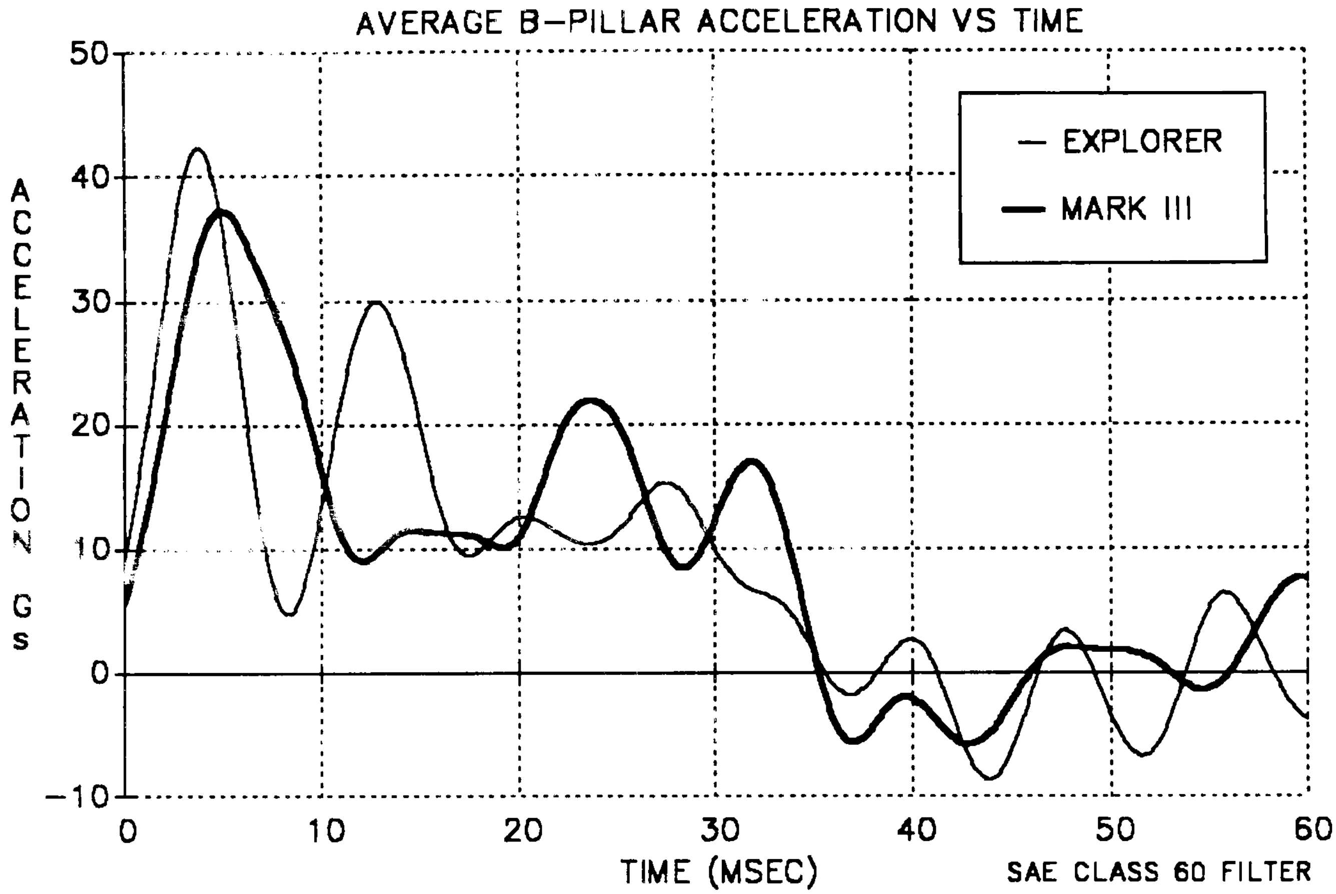
Results

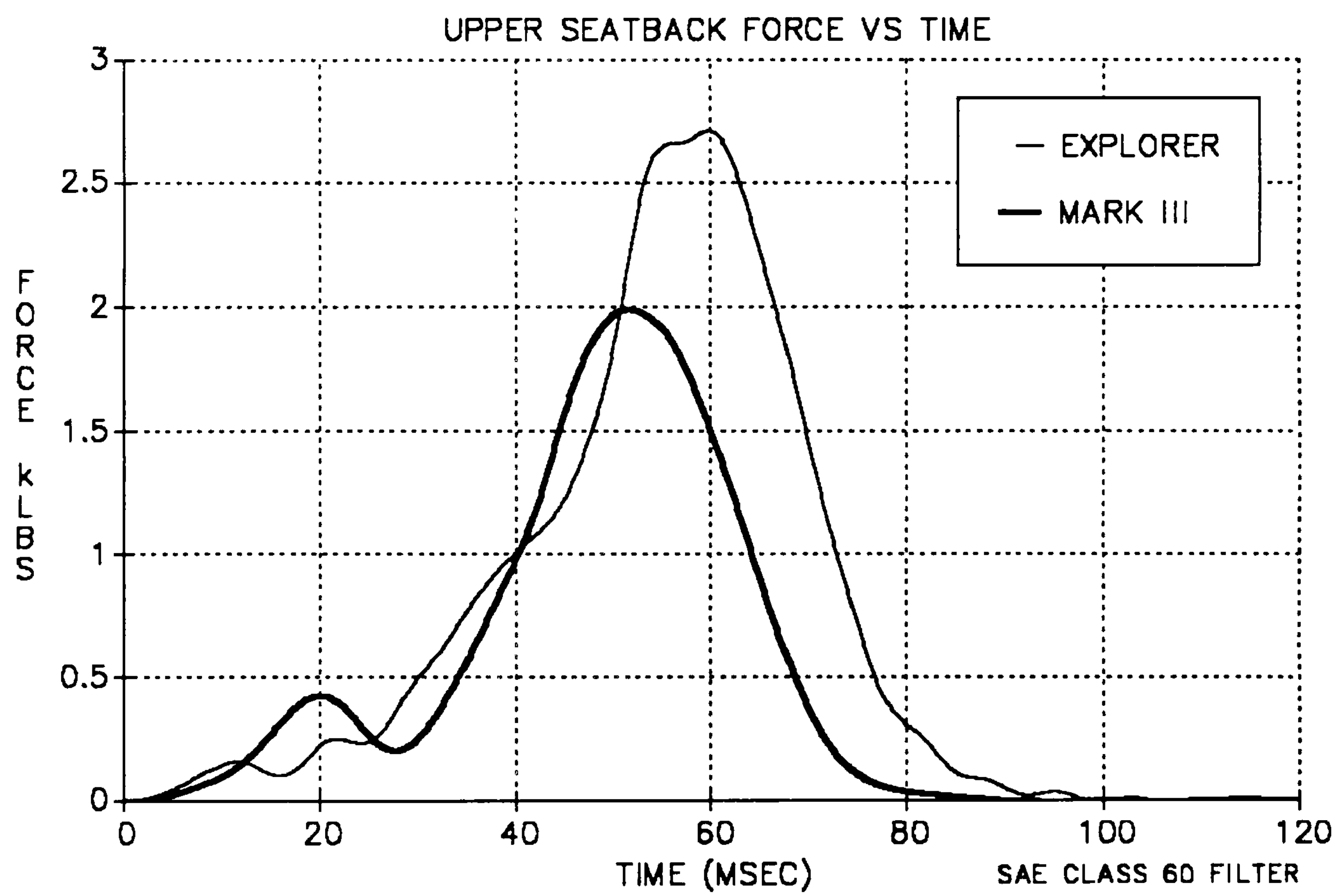
The following table summarizes the results of the two tests.

	Explorer Van	Mark III Van
Impact Velocity (mph)	29.5	29.5
Injury Data	2nd Seat Left - 50th HIII HIC (full dur.) = 58 Clip (Gs) = 9 Peak neck force (lbs) = 468 Peak neck moment (in-lbs) = 192	Sofa Seat Center - 50th HIII HIC (full dur.) = 46 Clip (Gs) = 10 Peak neck force (lbs) = 130 Peak neck moment (in-lbs) = 184
	2nd Seat Right - 95th HIC (full dur.) = 58 Clip (Gs) = 23	
	Sofa Seat Center - 50th HIII HIC (full dur.) = 213 Clip (Gs) = 11 Peak neck force (lbs) = 294 Peak neck moment (in-lbs) = 348	
Seatback Peak Load (lbs)	2710	1990
Seat Structural Damage	Very limited local deformation of seatback tubing and/or recliner mechanism	Very limited local deformation of seatback tubing and/or recliner mechanism
Dummy Kinematics	Restrained by seating system and remained in the seat throughout event	Restrained by seating system and remained in the seat throughout event

Table 2 - Summary of the Results

As can be seen by the results presented in Table 2, the injury numbers of the test dummies were quite low. Also the seat remained structurally intact. No large deformation or catastrophic failure occurred in any of the seats. The following plots show the data for the vehicle longitudinal acceleration and the seatback dynamic load. The seatback peak dynamic load for the Explorer van was 2710 pounds and 1990 pounds for the Mark III van. The difference was because a 95th percentile dummy was used in the Explorer van and a 50th


AVERAGE B-PILLAR ACCELERATION VS TIME
EXPLORER
MARK III
ACCELERATION Gs
50
40
30
20
10
0
-10
0
10
20
30
40
50
60
TIME (MSEC)
SAE CLASS 60 FILTER


UPPER SEATBACK FORCE VS TIME
EXPLORER
MARK III
FORCE kLBS
3
2.5
2
1.5
1
0.5
0
0
20
40
60
80
100
120
TIME (MSEC)
SAE CLASS 60 FILTER

percentile dummy was used in the Mark III van.

A component test was performed on an Explorer van captain chair, identical to the one that had the load cell tethered to it. A static rearward load was applied to the upper most seatback tube using a hydraulic cylinder, while measuring the pull force. The seat was rigidly fixtured to a test bed, with a similar mounting method as in the vehicle. Failure of the seat tubes began at 1150 pounds, while the dynamic load reached 2710 pounds without any significant failure. The difference in peak loads can be contributed to the fact that the component test is performed independent of the influence of the rest of the vehicle, while the full vehicle test has a system response.

There are two FMVSS component tests that measure the strength of a seatback. The first is FMVSS 202, "Head Restraints", which requires a static load of 200 pounds applied rearward through the head restraint. The seat must sustain this load while not deflecting more that 4 inches rearward of the displaced torso reference line. The second is FMVSS 207, "Seating Systems", which has five parts to its requirements, not all of which are applicable. For this type of seat, a static load of 20 times the weight of the seat assembly would be applied through the center of gravity (CG), both in the fore and aft directions. Also, a static moment of 3300 in-lbs/occupant would be applied rearward at the upper seatback tubing. An optional part of the standard requires a dynamic acceleration of 20 Gs in the longitudinal direction opposite to that in which the seat folds.

Conclusions

The injury results for both tests showed a favorable response of the dummies to the rear impact. The seatback strength was sufficient enough to restrain each of the dummies, without sustaining any permanent deformation in the seat structure.

Also, a methodology was established to evaluate the dynamic seatback load in a rear impact crash. With the reaction structure at the front of the vehicle constructed with sufficient strength, the seatback loads were measured with confidence. This methodology was used to show that the seatback loads during a dynamic rear impact were much higher than the seat can withstand in a static pull test. During the crash event, other means of absorbing energy are present, while in a static pull test, the seat is rigidly fixed. This brings up a concern of whether the static FMVSS test procedures used to evaluate seatback strength are representative of real world loads.

Another point of importance is that the test vehicles were significantly heavier than the flat faced moving barrier. The FMVSS 301 standard is applicable to passenger cars, MPV's, trucks, and buses with a gross vehicle weight rating (GVWR) of 10,000 pounds or less. Most passenger cars that are tested in rear impacts weigh less than the moving barrier. A vehicle lighter than the moving barrier would see a greater change in velocity imparted to the vehicle and occupants than was experienced in the tests with these conversion vans. A larger change in velocity can contribute significantly to the potential for seatback failure and occupant injury.

DISCUSSION

PAPER: **Investigation of Occupant Injury Potential in Vehicle Rear Impacts**

PRESENTER: Donald Crane

QUESTION: Pat Kaiker, Chrysler Corporation
Your investigation was of vehicles that were in production, correct, not prototype vehicles?

ANSWER: These are production Chevrolet G-vans, that's right.

That's what I thought. Thank you.

Q: Y. King Liu, University of Iowa
What's different about these seats that the seat backs do not fail? For most passenger car tests using 301, the seats collapse?

A: Part of that could be the fact that for the vehicles of heavier weight, their change of velocity is not as great for these heavier vehicles. The other thing is that the vans are concerned, the van conversion companies are very concerned with their seats and they take a lot of pains to evaluate their seat because that is what one of the major conversion investigations are for 207 and 210. There is nothing really unusual about the seat or is it strengthened in any way.

Q: Keith Friedman, Friedman Research
I was wondering if you had considered the question since they're concerned about what's going to happen in the real world, the issue of an offset rear impact for the rear seat occupants and the effect of not having seven dummies, but rather say two, one in the rear seat and in the driver's seat, and the implications for the seat back strength in that rear seat position.

A: We didn't look at that right now, that's an interesting point to bring up and that may be future work, but we just at this time want to try to evaluate dynamics and what the seat back loads were and how that related to FM VFS testing.

Thank you.